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6. AUTHOR(S)
Christopher D. Jones

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Physics Laboratory
University of Washington
1013 NE 40th St.
Seattle, WA 98105-6698

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy St.
Arlington, VA 22217-5660
Attn: James E. Eckman (Code 322BC)

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The work reported here was a collaboration with Peter A. Jumars of the University of Maine.

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13. ABSTRACT (Maximum 200 words)

This is a report of the field test of a "portable acoustic laboratory," a set of observational tools that can be used for *in situ* testing of the effects of organisms, biological processes, and benthic structures on underwater acoustic propagation in sediments. A test was conducted off the end of a pier at the Friday Harbor Laboratories of the University of Washington. A semicircular region of seabed was monitored for several weeks, then clean sand was spread over two muddy patches. Monitoring showed a sudden drop in backscatter, but this was short lived. Abundant mysid shrimp appeared to have caused microtopographic changes that quickly raised backscatter intensity to near-background levels. Subsequent introduction of burrowing thalassinid shrimp had the anticipated effect of enhancing backscatter above background and pre-sand-layer levels.

It is anticipated that this kind of portable laboratory will be able to answer many specific questions about potential biological effects on backscatter. For example, how does the acoustic signature of a mine-like object change as organisms foul the exposed surfaces? And, how does the acoustic coupling of such an object with overlying water and underlying sediments) change in the presence of bioturbation and geochemical processes?

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Effects of Biota on Backscatter: Experiments with the Portable Acoustic Laboratory (PAL)

Christopher D. Jones
Applied Physics Laboratory
Campus Box 355640
University of Washington
Seattle, WA 98195-5640
phone: (206) 543-1615 fax: (206) 543-6785 email: cjones@apl.washington.edu

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LONG-TERM GOALS

Two long-term goals intersect in the short-term objectives of this research. Jumars' long-term goal is to identify, quantify and understand important interactions among organisms, particles (including sediments), solutes and moving fluids. The reason for this goal is to enable solutions of interesting forward and inverse problems dealing with benthic biota. This work is joint with Chris Jones of the Applied Physics Laboratory at the University of Washington. As an ocean acoustician, Jones' long-term goal is to understand both the mechanisms by which benthic biota affect high-frequency (HF) scattering from sediments and their impacts on existing Navy models and systems. A better understanding of the biological causes of heterogeneity in sediment will add to the general understanding of HF acoustic interaction with the seafloor, aid in interpretation of HF seafloor imagery, and aid in the detection and identification of objects in biologically active sediments.

OBJECTIVES

Our common short-term objective is to provide acoustical tools for forward and inverse problems dealing with benthic biology. Namely, we seek to develop a rapidly deployable, inexpensive capability to do reductionist, mechanistic experiments concerning the effects of organisms, biogenic structures and benthic structures in general on acoustic propagation in sediments.

APPROACH

The underlying precept of this work is that one of the limitations on progress in understanding acoustic propagation, particularly at low angles of incidence with the sediment-water interface, is the lack of a laboratory facility that can realistically accommodate biological processes that may be important in affecting acoustic propagation. The primary means currently available to test ideas about biological effects on propagation is as projects embedded in episodic and expensive field experiments that require ship time and deployment configurations that are difficult to change "on the fly." An indoor laboratory cannot easily remove this impediment to research progress for many reasons, some of which are acoustic and some biological. Particularly at low angles with the seabed, echoes in laboratory tanks are acute problems. Another major issue in laboratory facilities is the formation or inclusion of gas bubbles in the sedimentary matrix. Yet another is the rapid degradation of "chunks" of the ecosystem brought into the laboratory to represent the natural system.

To circumvent many of these difficulties, we have developed the concept of a portable field laboratory (PAL), a set of observational tools that can “plug and play” wherever there is a source of power into and a conduit for information out from the sea. One of the assets of such an experimental facility is a known fauna and sedimentary structure, so a logical initial target is the end of the pier at an existing marine laboratory, and we have begun at the Friday Harbor Laboratories of the University of Washington. The assets are portable, however, and can be moved to another marine laboratory, or arbitrary coastal site, and this facility represents one kind of package that might be plugged into future networks of benthic marine observatories. Although our current pressure casings have limited depth capability, the same is not true of the concept.

As a proof of concept, we designed an experiment around the classic conceptual model of bioturbation, in which distinct, emplaced layers are “mottled” by initial bioturbation. As bioturbation proceeds, the layers are homogenized. We predicted a peak in acoustic backscatter due to volume heterogeneity at an intermediate stage of bioturbation.

WORK COMPLETED

As the test project, we first monitored a semicircular region of seabed off the Friday Harbor pier for several weeks. We then spread clean foundry sand over two patches of muddy seabed, each approximately 4 m^2 in area (Fig. 1). We next monitored for several days, and then transplanted thalassinid shrimp to each plot to accelerate bioturbation. Unfortunately, the 300-kHz transducer malfunctioned and was not available for the study.

RESULTS

Immediately upon emplacement, the two sand patches showed decreased backscatter relative to levels before emplacement or to levels nearby (Fig. 1). The sudden drop, however, was short lived (Fig. 2). Abundant mysid shrimp on the bottom appeared to be a primary cause of microtopography that quickly raised backscatter intensity to near-background levels. Our manipulation of adding burrowing, thalassinid shrimp had the anticipated effect of enhancing backscatter above background and above pre-sand-layer levels, as we had predicted.

IMPACT/APPLICATION

We anticipate that this kind of portable field laboratory will be useful for answering many specific questions about potential biological effects on backscatter. For example, in the benign setting of a field laboratory, it is feasible to deploy mine-like objects and monitor how their acoustic signatures change as organisms foul their exposed surfaces and bioturbation and perhaps geochemical processes alter their acoustic coupling with overlying water and underlying sediments.

RELATED PROJECTS

This work is a collaboration between Chris Jones of the Applied Physics Laboratory, University of Washington (N00014-00-1-0034), and Pete Jumars of the University of Maine component. The titles and texts of these two grants (N00014-00-1-0034 and -0035) are identical.

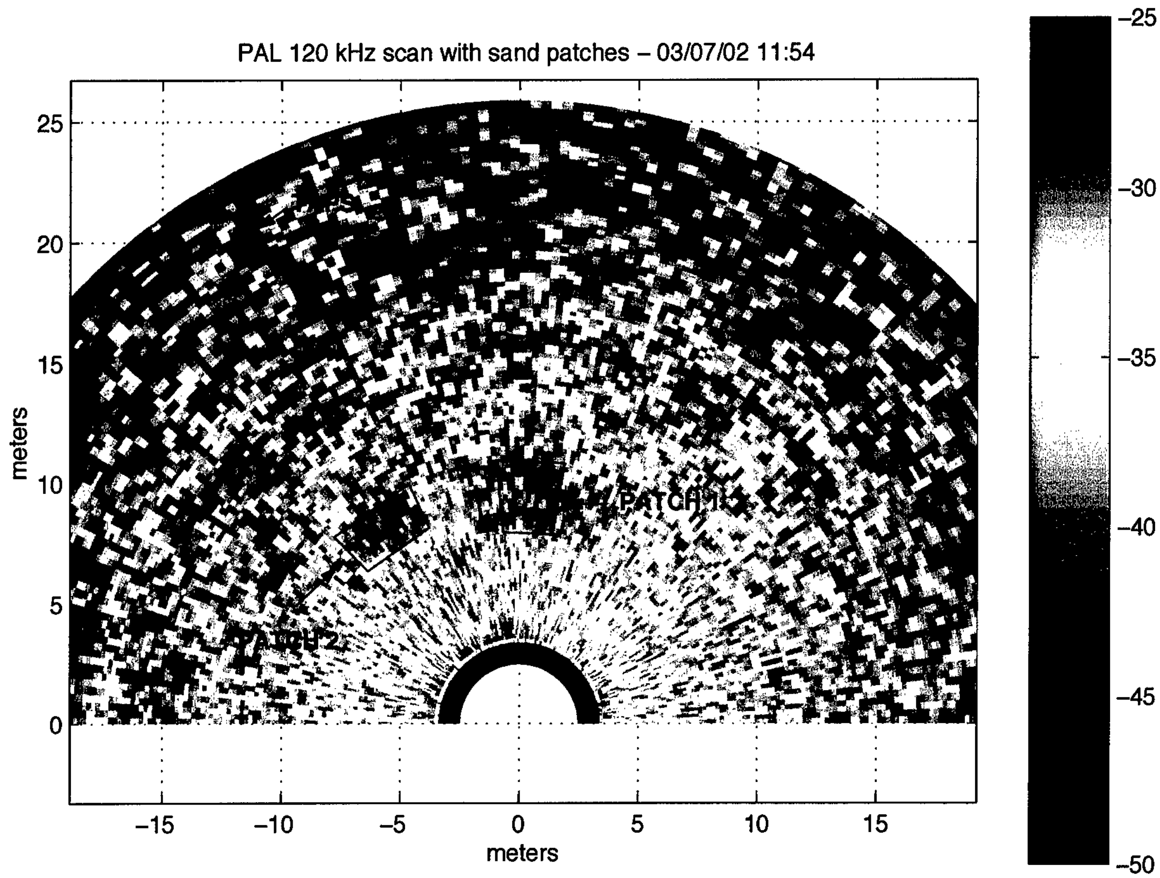

Figure 1. Backscatter at 120 kHz immediately after emplacement of two sand patches. Note the reduced backscatter of the two sand patches and the high backscatter from the TAPS-6 (six-frequency Tracor Acoustic Profiling System) in the field of view of the sonar.

This project is part of a more general long-term effort on our parts to develop means of detecting benthic organisms and their activities over unprecedented scales (notably over large areas and short times compared to any sampling methodology used previously) and to determine their impacts on acoustic propagation. It was fueled by two empirical studies suggesting biological effects on backscatter (Jumars et al. 1996; Briggs and Richardson 1997) and a theoretical one showing that temporal decorrelation in backscatter at some sites is consistent with a simple model of bioturbation (Jones and Jackson 1997). We followed up with experimental manipulations to test that hypothesis (Self et al., 2001). SAX99 extended these efforts to sediments with greater sound-speed contrasts (with sound speed in overlying seawater; Richardson et al. 2001 and in preparation). This work on biological and biogenic effects has been done in collaboration with Richardson and Briggs of NRL Stennis. Their measurements for Orcas were embedded in Self et al. (2001), and we have mutually agreed that our manipulations in SAX will be embedded in a broader manuscript on SAX99 manipulations that they will lead.

One of the questions arising from the SAX99 results was how fast fish feeding could modify bottom microtopography. This question is being pursued in a short modeling study by Sara Lindsay and Pete Jumars (N00014-02-1-0091).

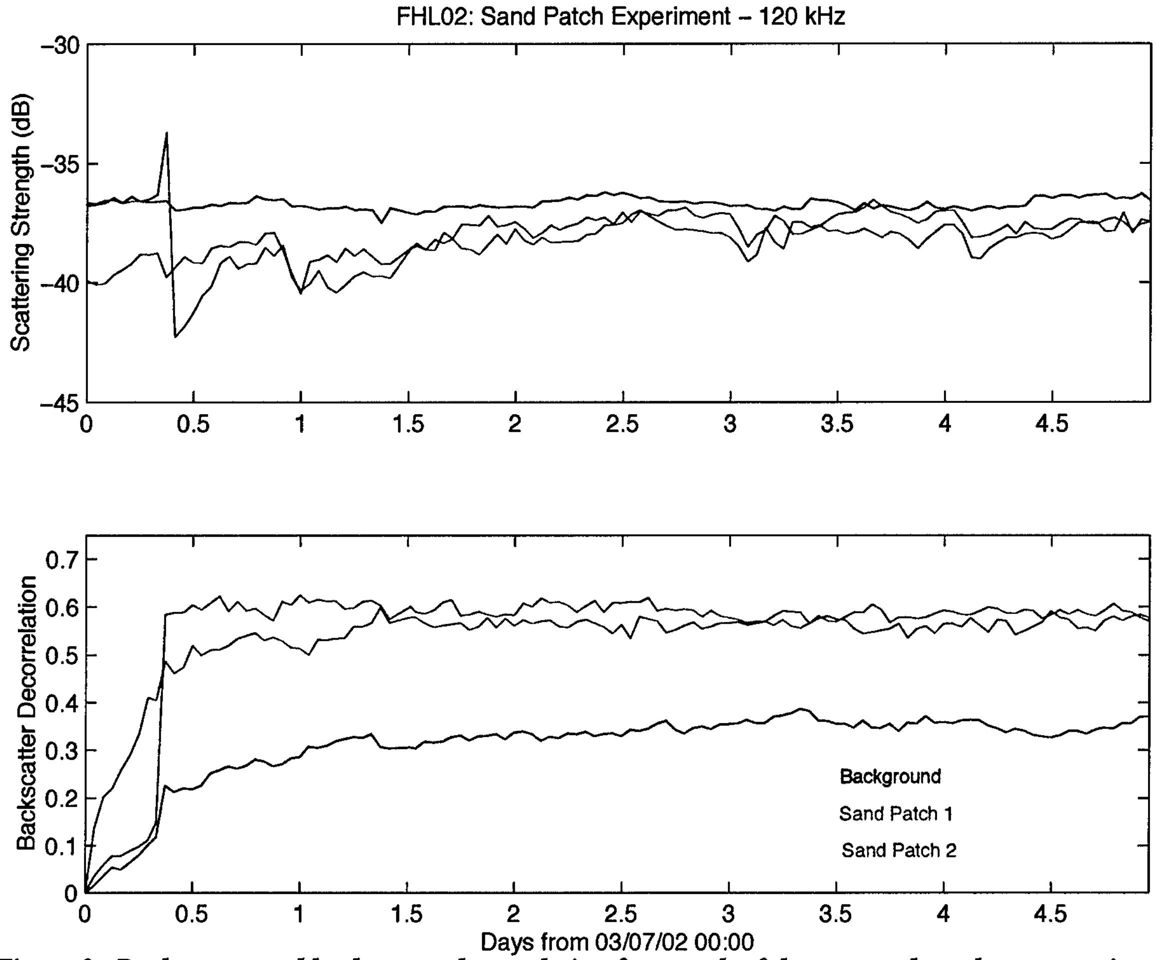

Figure 2. Backscatter and backscatter decorrelation from each of the two sand patches versus time. The reduced backscatter effect is nearly gone after only two days. Decorrelation of the returning 120-kHz wave form within the patches, however, remains much higher than in ambient sediments for more than five days.

Under separate funding, Pete Jumars at the University of Maine is also working with the related phenomenon of emergence by seabed fauna that may influence both surface microtopography and volume heterogeneity. This complementary grant is entitled "Shallow Scattering Layer (SSL): Emergence Behaviors of Coastal Macrofauna" (N00014-00-1-0662). It is also an informal collaboration with Van Holiday of BAE SYSTEMS, Inc., with whom we have completed a manuscript on emergence behaviors (Kringel et al., in review). Van Holliday has decided that the data warrant development of a more geometrically accurate (than the bent cylinder) model of the mysid body for purposes of inversion.

REFERENCES

Briggs, K.B., and M.D. Richardson. 1997. Small-scale fluctuations in acoustic and physical properties in surficial carbonate sediments and their relationship to bioturbation. Geo-Marine Lett, 17: 306-315.

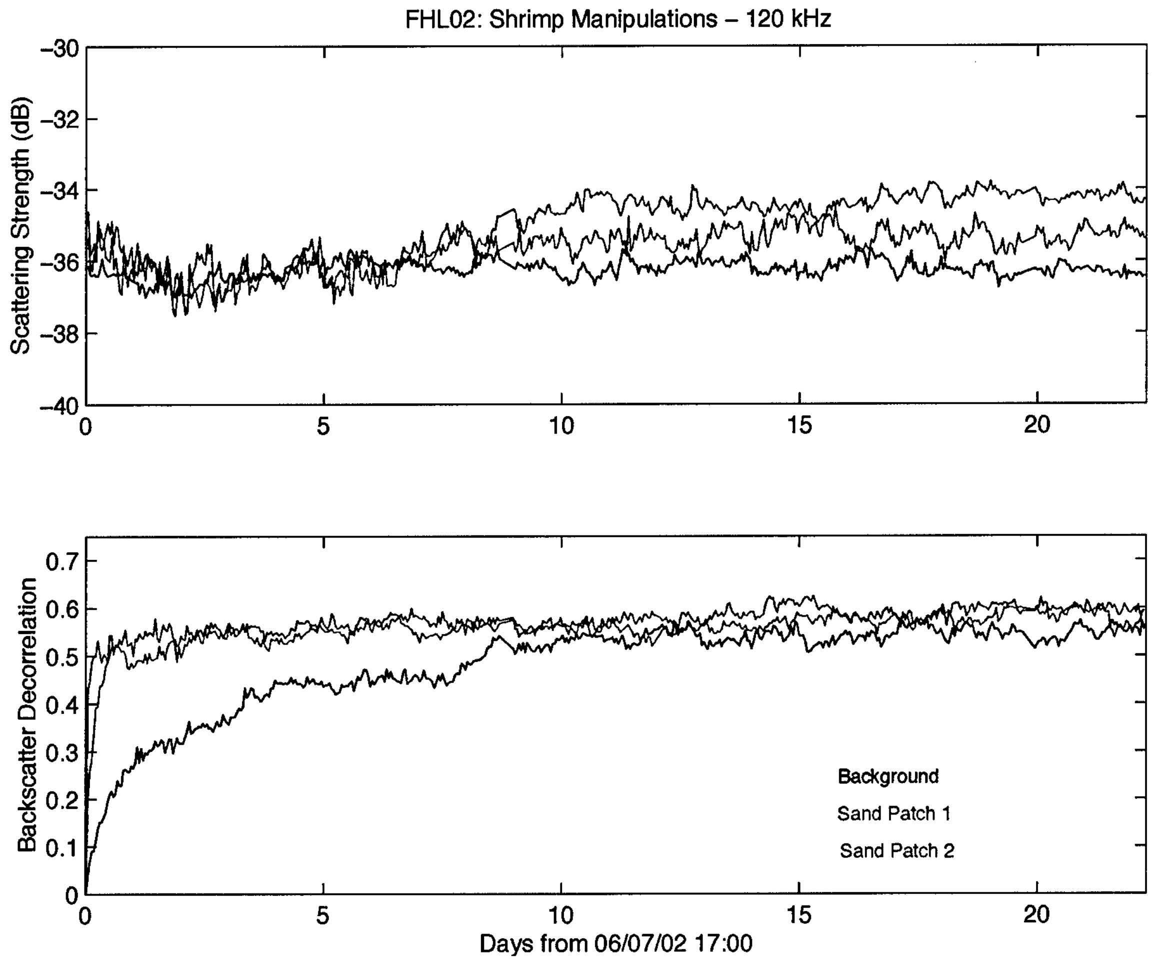

Figure 3. Backscatter and backscatter decorrelation from the two patches over time after the introduction of burrowing, thalassinid shrimp. Both are enhanced by the manipulation, but the backscatter increase lasts more than three weeks whereas the decorrelation effect is largely limited to the first week.

Jones, C., and D. Jackson. 1997. Temporal correlation of backscatter due to bioturbation in marine sediments. Saclantcen Conference Proceedings CP-45: High-Frequency Acoustics in Shallow Water, Lerici, Italy, July, 1997.

Jumars, P.A., D.R. Jackson, T.F. Gross and C. Sherwood. 1996. Acoustic remote sensing of benthic activity: A statistical approach. Limnol. Oceanogr. 41: 1220-1241.

Kringel, K., P.A. Jumars and D.V. Holliday. High-frequency acoustic assessment of nocturnal vertical migration from the seabed: the shallow scattering layer, revision resubmitted to Limnol. Oceanogr.

Richardson, M.D., K.B. Briggs, L. Dale Bibee, P. A. Jumars and others. 2001. Overview of SAX99: Environmental considerations. IEEE J. Ocean Eng. 26: 26-53,

Self, R.F.L. P. A'Hearn, P. A. Jumars, D. R. Jackson, M. D. Richardson and K. B. Briggs. 2001. Effects of macrofauna on acoustic backscatter from the seabed: field manipulations in West Sound, Orcas Island, WA, USA, J. Mar. Res. 59: 991-1020.